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Leatherback Turtles in Southeast U.S. Waters

by

Nancy B. Thompson and Hoalan Huang

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Notice

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Copies may be obtained in writing from:

Dr. N. B. Thompson

NMFS/SEFSC

75 Virginia Beach Dr.

Miami, FL 33149

or

NTIS

5288 Port Royal Rd.

Springfield, VA 22161

INTRODUCTION

The leatherback turtle, Dermochelys coriacea, is a circumglobal species which is currently divided into two subspecies. The subspecies *D.c. coriacea*, inhabits waters of the western Atlantic Ocean from New Foundland to northern Argentina (Marquez 1990). According to Marquez (1990) this species is considered to be "highly pelagic... that approaches coastal waters only during the" nesting season or following food resources. Coastal waters are typically defined by the extent of the continental shelf. Off the southeast coast of the U.S., the shelf extent is delimited by the western boundary of the Gulf Stream. In southeast U.S. coastal waters, leatherback turtles have been observed in coastal waters along the Florida east coast (Schroeder and Thompson 1987). However, the extent of the occurrence in coastal waters from North Carolina to Key West Florida has not been defined. The objectives of our analyses are to 1) determine if leatherback turtles are present in coastal waters and if distributions are seasonally or spatially predictable, 2) attempt to determine if sea surface temperature can be used to predict turtle presence and 3) determine if turtle mortality as indexed by carcass wash-ups can be related to offshore shrimp fishing effort.

Two major data bases maintained by the Southeast Fisheries Science Center include information on turtles in coastal waters of the southeast U.S. These two data bases, resulting from aerial surveys and from sampling for wash-ups of dead turtles, were evaluated to define the presence of leatherback turtles and to determine the seasonal distribution of turtles in coastal waters along the southeastern United States. The data on turtle wash-ups were evaluated to determine if occurrences of wash-ups were related to shrimp trawling in coastal waters along the southeast as has been demonstrated for loggerhead and Kemp's ridley sea turtles (Henwood and Stuntz 1987).

Reports of dead turtles that wash up on the coast (heretofore referred to as strandings) are reported to the SEFSC through the Sea Turtle Stranding and Salvage Network (STSSN). The STSSN data base includes data from beaches sampled for carcasses (Thompson and Martinez 1990; Teas 1992). While it is generally not possible to assign a definitive cause of death to these strandings, statistical relationships between commercial shrimp trawling activities and the magnitude of strandings have been described (Magnuson et al. 1990; Caillouet, Jr. et al 1991).

DATA SOURCES AND ANALYTICAL METHODS

AERIAL SURVEY

From 1982 through 1984, seasonal aerial overflights were conducted by the SEFSC from Cape Hatteras, N.C. to Key West, FL. (Thompson 1984). Surveys were completed from the coastline over coastal waters out to the approximate mean western boundary of the Gulf Stream. Seasonal surveys that corresponded to spring (April/May) and summer (July/August) were completed in all three years. Fall (October/November) surveys were completed in 1982 and 1983 and a single winter survey was completed in January/February 1983.

All surveys were conducted in a Beechcraft AT-11. This aircraft is equipped with a plexiglass bubble in the nose that allows for the unobstructed observation of the trackline out to the horizon. This platform can accommodate two observers at any given time.

The bubble nose was calibrated to obtain right angle distance from any observed object to the trackline. With this information line transect methods of density estimation can be applied. With the instrumentation interfaced with an onboard computer the time and location of all observations were immediately reported. Other airplane instrumentation was also interfaced with an onboard computer and provided for the immediate reporting of sea surface temperature, aircraft altitude and speed. In general, the aircraft was maintained at 500 ft. altitude and a ground speed of about 120 knots (Shoop and Thompson 1983).

The entire study area of about 29,000 nm^2 was divided into 10 sampling areas, each of which could be sampled on a single flight day and of nearly equal area(Figure 1). In the first summer survey, two Gulf Stream areas were sampled (Figure 1). The purpose of including these areas was specifically to target presumably pelagic leatherback turtles. Transects within each sampling block were randomly selected to represent about 8% coverage of surface water. Transects were oriented in a northwest to southeast direction to minimize glare and optimize coverage over depth. No inshore waters were sampled during this program.

All turtles were reported to species level when possible. Location as latitude and longitude, time of sighting, aircraft altitude and speed, and sea surface temperature were automatically recorded via computer. Sea state, glare amount and other information were added to the computer record by a resting observer.

The distribution of individual sightings were pooled over seasons as appropriate to maximize sample sizes for the estimation of density. Density was estimated using line transect methods such that the frequency distribution of sightings classified by right angle distance interval is transformed into a probability density function (pdf). The major assumption with this method is that animals on the trackline are observed with a probability of 1.0. The function which describes the pdf, is selected based on the best fit and robust model criteria described by Burnham et al (1980). The intercept of this pdf is used in the estimation of density (D) as:

$$D = nf(0)/2L$$

n = number of total sightings

f(0) = pdf evaluated at right angle distance = 0

L = total transect miles flown

The standard error (SE(D)) of this estimate was computed as:

$$SE(D) = D^{*}sqrt(1/n + ((SE(f(0))/f(0))2)$$

In this way, the error associated with the estimation of f(0) is incorporated (Buckland 1985).

Sighting rates of turtles were also computed for each season. Sighting rates are defined as the number of turtles sighted per nm of linear transect flown and can be directly compared. Standard errors were computed simply as the standard error of the number of observations per transect as:

$$SE(n) = r((n'-n)2/r-1)/n2$$

n = sightings per transect

n' = mean number of sightings per transect

r = number of total transects

To evaluate the mechanisms determining distributions, sea surface temperature (SST) data as obtained by Advanced Very High Resolution Radiometry (AVHRR) satellite were overlaid the observed seasonal sightings. The SST data used are at 1 km resolution. In this way, a visual evaluation of distributions relative to sea surface temperature was accomplished.

SEA TURTLE STRANDING AND SALVAGE NETWORK

In 1987 with the promulgation of requirements in the shrimp trawl fishery to utilize Turtle Excluder Devices (TEDs), the SEFSC initiated sampling for turtle carcasses by direct periodic observations of selected beach areas. The sampling zones correspond to the statistical zones established by NMFS to report shrimp trawl effort (Figure 2). These zones along the southeast coast originally included 28-29, 31, and 32. Zone 30 was added in December 1988 in response to the occurrence of large numbers of turtle strandings. The sampling regime within these areas has been previously described (Thompson and Martinez 1990; Caillouet, Jr. et al 1991.). In short, sampling effort was accomplished weekly or bi-weekly over these zones. Sampling was conducted via aerial or beach survey depending on the zone. In this way, mortality is measured per total miles sampled on a given sampling day.

Estimates of mortality per unit of sampling effort (MPUE) were completed for each zone and month by years from 1987 through 1992 as in Thompson and Martinez (1990). These MPUE values were evaluated with monthly shrimp effort to determine if a statistical relationship between MPUE and shrimp effort could be measured.

SHRIMP EFFORT INFORMATION

Shrimp effort information was provided by the SEFSC statistics division. Effort is reported by fishermen as time fishing. This value is converted to a 24 hour day fished, such that this value represents the total number of 24 hour periods that nets were in the water. This effort value has been used before and is preferred over pounds landed or total trips because the 24 hour daysfished measure represents the actual time that a turtle could be captured during any fishing trip (Thompson and Martinez 1990).

Shrimp effort information was combined by shrimp species captured and is reported by statistical zones that are consistent with those used to report turtle strandings. These values were estimated by zone, month, and year and compared with estimated MPUE.

RESULTS

AERIAL SURVEYS

The total number of sightings and transect miles flown for each season are shown in Table 1. Included are the totals over the entire study area, Blocks 1-10, and within the area from blocks 3-8, which represents the shelf waters adjacent to the Blake Plateau (Table 1). Values for total miles flown and total sightings of leatherback turtles were pooled over the years each seasonal survey was flown. The number of leatherback turtle sightings totaled 281 over all surveys. The highest number of sightings occurred in the summer with 150 sightings representing 53% of the total sightings. In block 8 in the summer a total of 114 leatherback turtles sightings were recorded, representing 40% of the total over all blocks and seasons.

Estimates of turtle density by season over all blocks and for the area represented by blocks 3-8 are presented in Table 1. The estimates of density reflect the distribution of sightings. Interestingly, the majority of sightings occurred within the area from blocks 3-8, with the highest value in the summer (.03452) (Table 1).

Estimates of leatherback turtle density by season and block and by season over the entire study area with standard errors are included in Table 2. Turtle density reflects the frequency of sightings by season, block, and study area. The summer density was highest (.18263) for all seasonal and block strata.

The estimates of density by season over all blocks, with 95 % confidence intervals as $\pm$ 2 standard errors are shown in figure 3. Turtle density is significantly higher in the summer as compared with the other three seasons. When comparing density estimates by block within a season, estimates cannot be statistically separated based on the overlap of 95% confidence intervals (Figures 4-7). This is the result of low density estimates with high error in at least one block per season. For this reason, in the summer in block 8, turtle density is significantly higher than in all blocks except block 6.

Density was also estimated for sampling blocks 3 through 8. This area is roughly equivalent to the southeastern shelf waters off South Carolina to Cape Canaveral, Florida and is the area of density uniformity in the spring. These estimates with standard errors are include in Table 1 and in figures 4-7. These values do not differ significantly from the estimates for the overall study area (Table 1 and figures 4-7).

Turtle density was estimated for the two Gulf Stream blocks and are included in Table 1. Only one leatherback turtle was sighted in each of these blocks resulting in standard error estimates equal to estimated density. Estimated density in these two blocks was relatively low as compared to other blocks during any season except for those when there were no sightings.

Sighting rates were computed by block and season, over blocks 3-8, and for the study area (Table 1). These results are consistent with the density estimates with the summer survey of block 8 with the greatest sighting rate of 5.03 turtles per 100 nm. Even within the area of highest turtle density, the rate of 5.03 per 100 nm transect flown results in one turtle sighted about every 20 nautical miles. Along a single transect, the highest sighting rate was measured within the summer survey, 1984, within block 8. Transect number 7 was 69.53 nm in length and 15 leatherback turtles were sighted over this transect. The rate along this transect was .22 turtles per linear nm or 22 turtles per 100 nm.

Sightings of leatherback turtles were plotted by season and sampling block for the study area (Figures 8 a-d). For the spring and summer, sightings from the respective surveys in 1982,1983 and 1984 were pooled. For the fall, sightings were pooled over 1982 and 1983. For the winter, sightings were separated by 1983 and 1992. The uniformity of sightings is shown in the spring. In the summer, sightings are clumped within block 8 . In the fall, the few sightings were made along the eastern boundary of the study area which corresponds to Gulf Stream boundary waters. In the winter, the spatial distributions of sightings in 1983 and 1992 appear different. In 1983, sightings were focused off South Carolina. In 1992, sightings were in the Cape Canaveral, FL area to the southern half of Georgia.

To determine if temperature is a factor defining turtle distributions, sea surface temperature was overlaid on the distributions for spring, summer, and fall of 1982 and winter of 1983 (Figures 9a-d). Warm water is depicted as yellow and changing to orange with increasing temperature. Water that is cool changes from color from green to blue with purple as the coldest water. In the spring 1982, average water temperature in the area of highest turtle concentration, within blocks 5 and 6, was 21.9° C. Sightings of turtles occurred in temperatures ranging from 15° to 24° C. In the summer 1982, turtles aggregated in block 8 with an average water temperature of 27° C while sightings were made in the warmest water in the block of 28.6° C which was in the Gulf Stream boundary waters. Notably, turtle appear to be found primarily within the cooler coastal waters in the summer. In the fall 1982, in blocks 1-4 and 8, turtles appear to line up along a thermal front where the measured change in temperature is 5° C.

Within blocks 6 and 7, turtles were sighted in the warmest water but the difference in temperature is less than 2^{o} C between the coolest and warmest waters. In the winter 1982, turtles again were sighted along a thermal front where the difference in temperature between the warm and cool water was 10^{o} C.

STRANDINGS AND SHRIMP FISHING EFFORT

Turtle mortality per unit of sampling effort was estimated by zone for zones 28-32 and pooled over the period 1987 through 1991 (Figures 10). High mortality values were estimated off Georgia for zone 31 in April and May with a secondary peak in October through December when zones 29, 30 and 31 off northeastern Florida and Georgia are combined .

Average monthly shrimp trawling effort was estimated using days fished for the period 1987-1991 (Figure 11). A relatively low but constant level of monthly effort occurred in zones 28 and 29, off the Florida east coast. The highest levels of effort were reported in zones 31 and 32 off Georgia and South Carolina over the period June through December. Levels of effort reported for zone 30 off northeastern Florida and southern Georgia were intermediate to the other zones except in November when effort in zone 30 was equivalent to zones 31 and 32 off Georgia and South Carolina.

A least squares linear regression was completed using mpue as the dependent variable and offshore shrimp fishing effort as the independent variable weighted by month. Data were pooled over zones (Figure 12). The regression did not produce statistically significant results (mpue=23.87-.005*days fished; $F=0.56$, $p=.4714$). Results indicate that the use of strandings in this way for this species does not provide insight into the relationship between strandings and fishing effort. A second regression, using the cumulative mpue and days-fished values by month was completed (Figure 13). This approach produced a statistically significant and positive relationship between the accumulation of strandings and the accumulation of fishing effort (cumulative mpue=43.81+.007*cumulative daysfished; $F=40.88$, $p=.0001$). This analysis demonstrated that there was high mortality with constant increases in monthly fishing effort during the spring (Figure 13). High mpue with low fishing effort may result when turtles aggregate and this aggregation occurs within an area with fishing effort and where carcasses have the opportunity to wash up on a sampling beach. These results indicate that as shrimping effort accumulated through the year, strandings increased (Figure 13).

DISCUSSION

The National Academy of Sciences described pelagic aerial surveys as a reasonable method to obtain information on the distribution of turtles on a synoptic or large scale over a short period of time. To this end, several aerial survey programs have been completed or are ongoing to quantify mammal and turtle distributions in the western Atlantic Ocean. The first such effort was mounted by the University of Rhode Island for coastal and pelagic waters from Maine to Cape Hatteras, N.C. in the late 1970's (Winn 1982). This program conclusively demonstrated that loggerhead and leatherback turtles at the surface of the water could be sighted from aircraft. The SEFSC initiated an aerial survey program in 1982 and Schroeder and Thompson (1987) reported on the distribution of leatherback turtles within a portion of this SEFSC study area along the southeast coast. To our knowledge, these results are the first described for this species over the southeastern portion of the United States.

There is no way to compare coastal and pelagic distributions of this species from these data since the limits of sampling were the coastal waters from North Carolina to Key West FL. The two study areas sampled within the Gulf Stream were relatively small and the very rapid sampling of these areas precludes any extrapolation of the density estimates. However, based on three years of sampling, it appears that leatherbacks are found in coastal waters although in much lower densities numbers than loggerhead turtles (Thompson 1987).

When comparing leatherback turtle densities between seasons and sampling blocks, the largest density was estimated for block 8 in the summer. This block also represented the area of highest loggerhead density which was computed for the spring (Thompson 1984). The summer surveys were completed in July and August which is not the peak nesting period for leatherback turtles on continental U.S. beaches (Magnuson et al. 1990; Marquez 1990). The coastal waters off Cape Canaveral Fl are known to be highly productive. Thus, it is more likely that leatherbacks are present as the result of the presence of food resources as suggested by Marquez (1990).

The first SEFSC investigation to determine if thermal cues might act to trigger turtle migrations was completed in 1988 (Sano and Fairfield 1988). They used sea surface temperatures as derived from AVHRR satellite to determine what magnitude of temperature change might trigger the migration of Kemp's ridley sea turtles from the northeast U.S. coast. Since this time, other studies have applied AVHRR satellite derived sea surface temperature to evaluate turtle distributions (Huang et al 1991; Anonymous 1992).

In our study it appears that temperature is not limiting which is expected since leatherback turtles are capable of maintaining an internal body temperature which is higher than ambient. This ability allows them to range as far north as Canada and as far south as Argentina in the western Atlantic. The presence of turtles along thermal fronts and in relatively cold water may be explained by the upwelling resulting along these fronts which trap and concentrate potential food resources. The existence of these fronts might be the best predictor of leatherback presence in relatively large numbers. To verify this, aerial overflights need to be timed to obtain real time sea surface temperature.

The number of strandings is useful to index mortality on a regional basis at the current level of sampling. Our results show that the accumulation of strandings was positively related to the accumulation of shrimp trawl effort over this region. However, assigning definitive cause of mortality to any individual stranded turtle can only be accomplished with an observer on board. Only observers on vessels can provide direct evidence of take with the added advantage of evaluating turtle condition upon release.

Our results show that leatherback turtles utilize coastal waters along the eastern seaboard. The presence of turtles appears to be related to the existence of thermal fronts which concentrate resources. This hypothesis is consistent with Marquez (1990). Because leatherback turtles are present in coastal waters, interactions between turtles and human activities such as fishing is likely. The relative impacts of these takes cannot be determined with the current data. Only through the use of observers can the magnitude of this take be measured.

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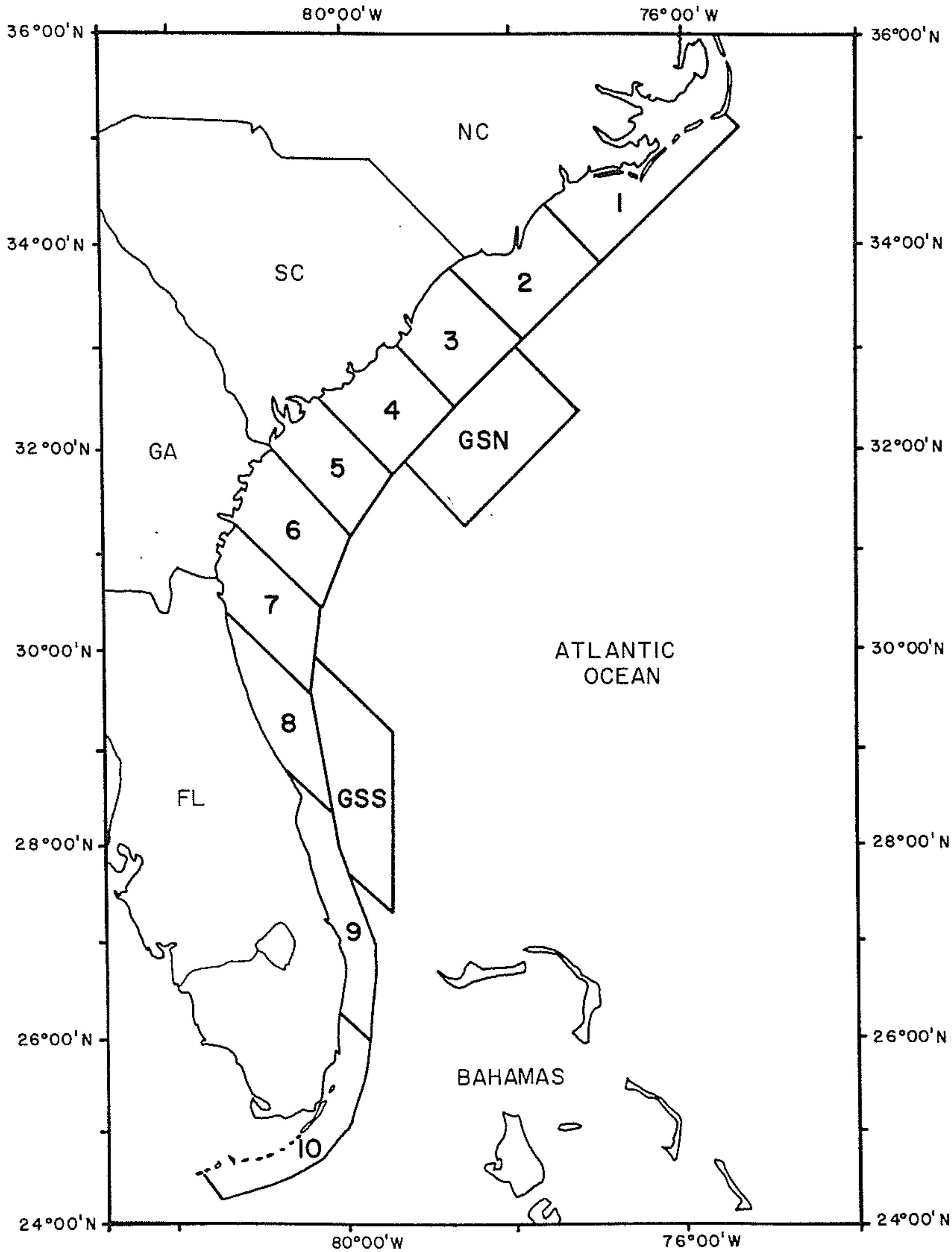
TABLE I. Total effort (nm), leatherback turtle sightings (turtles), density ($\hat{D}$) as turtles/nm^2, with standard errors (SE($\hat{D}$)) and sighting rate (SR) as turtles/nm. GSN = Gulf Stream North, GSS = Gulf Stream South

Blocks 1-10	**nm**	**Turtles**	**($\hat{D}$)**	**(SE($\hat{D}$)**	**SR**
Spring	22,406	103	.017	.0017	.0046
Summer	15,780	150	.035	.0030	.0095
Fall	8,710	17	.008	.0023	.0020
Winter	5,429	11	.008	.0028	.0020
Blocks 3-8					
Spring	13,759	75	.020	.0024	.0055
Summer	9,682	128	.048	.0045	.0132
Fall	5,424	11	.008	.0028	.0020
Winter	3,864	11	.012	.0039	.0028
Gulf Stream					
GSN	329	1	.011	. 011	.0030
GSS	434	1	.008	. 008	.0023

TABLE 2. Density ($\hat{D}$) as turtles/nm^2, with standard errors (SE($\hat{D}$)) and sighting rate (SR = turtles/nm). Estimates are stratified by block and pooled by season. Block = sampling block as shown in Figure 2.

	BLOCK									
	1	2	3	4	5	6	7	8	9	10
SPRING										
($\hat{D}$)	.004	.040	.031	.024	.019	.013	.009	.020	.002	0
(SE($\hat{D}$)	.003	.008	.007	.006	.006	.004	.004	.006	.002	0
SR	.001	.011	.010	.007	.005	.004	.003	.006	.001	0
SUMMER										
($\hat{D}$)	.007	.005	.006	0	.008	.002	.015	.183	.030	0
(SE($\hat{D}$)	.004	.004	.004	0	.005	.002	.005	.018	.007	0
SR	.002	.001	.002	0	.002	.001	.004	.050	.008	0
FALL										
($\hat{D}$)	.025	0	.006	.016	0	.009	.006	.004	.004	.005
(SE($\hat{D}$)	.013	0	.006	.007	0	.006	.006	.005	.004	.005
SR	.006	0	.001	.004	0	.002	.002	.001	.001	.001
WINTER										
($\hat{D}$)	0	0	0	.018	.031	0	.006	.013	0	0
(SE($\hat{D}$)	0	0	0	.011	.015	0	.006	.009	0	0
SR	0	0	0	.004	.008	0	.001	.003	0	0

List of Figures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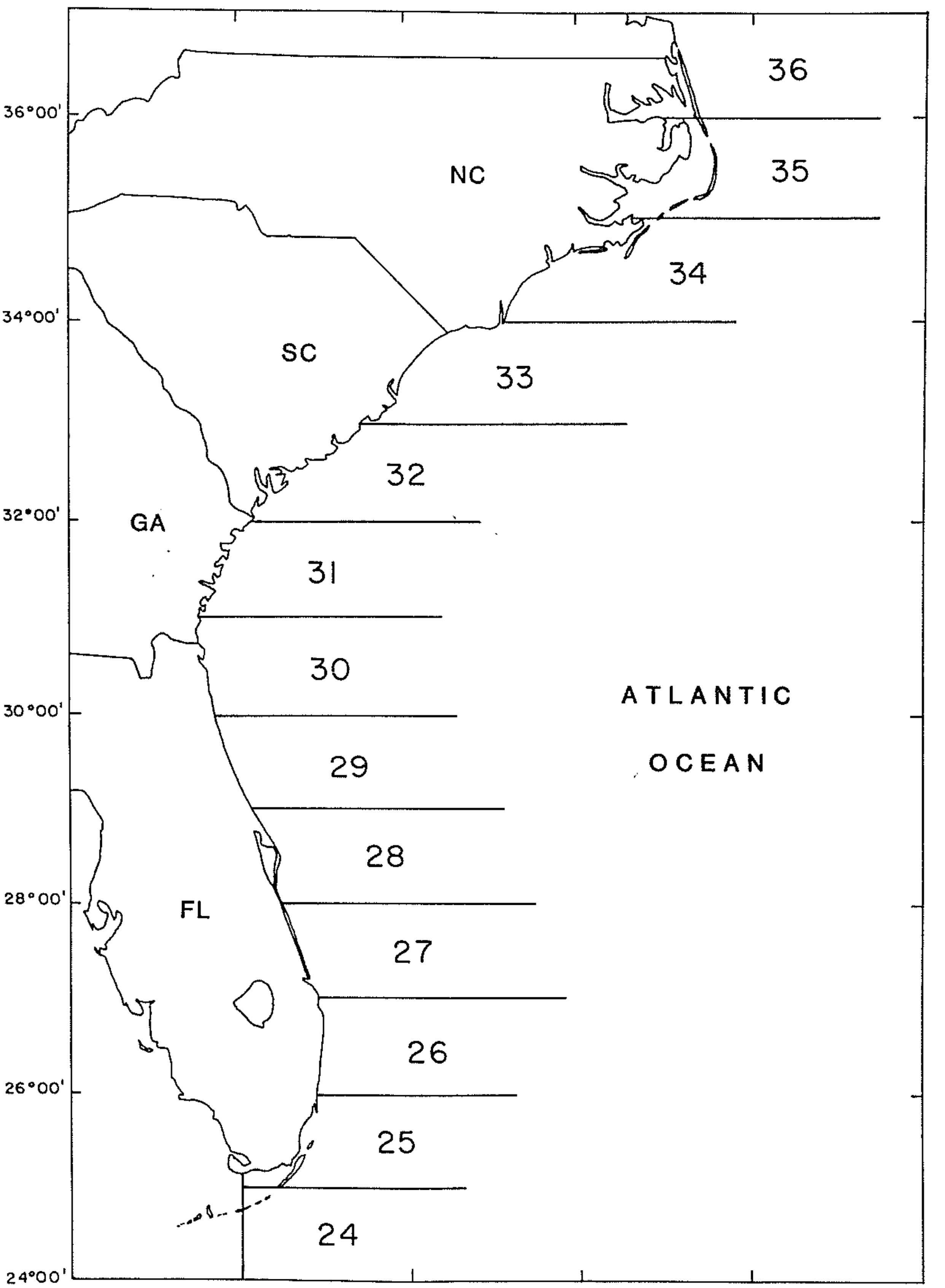
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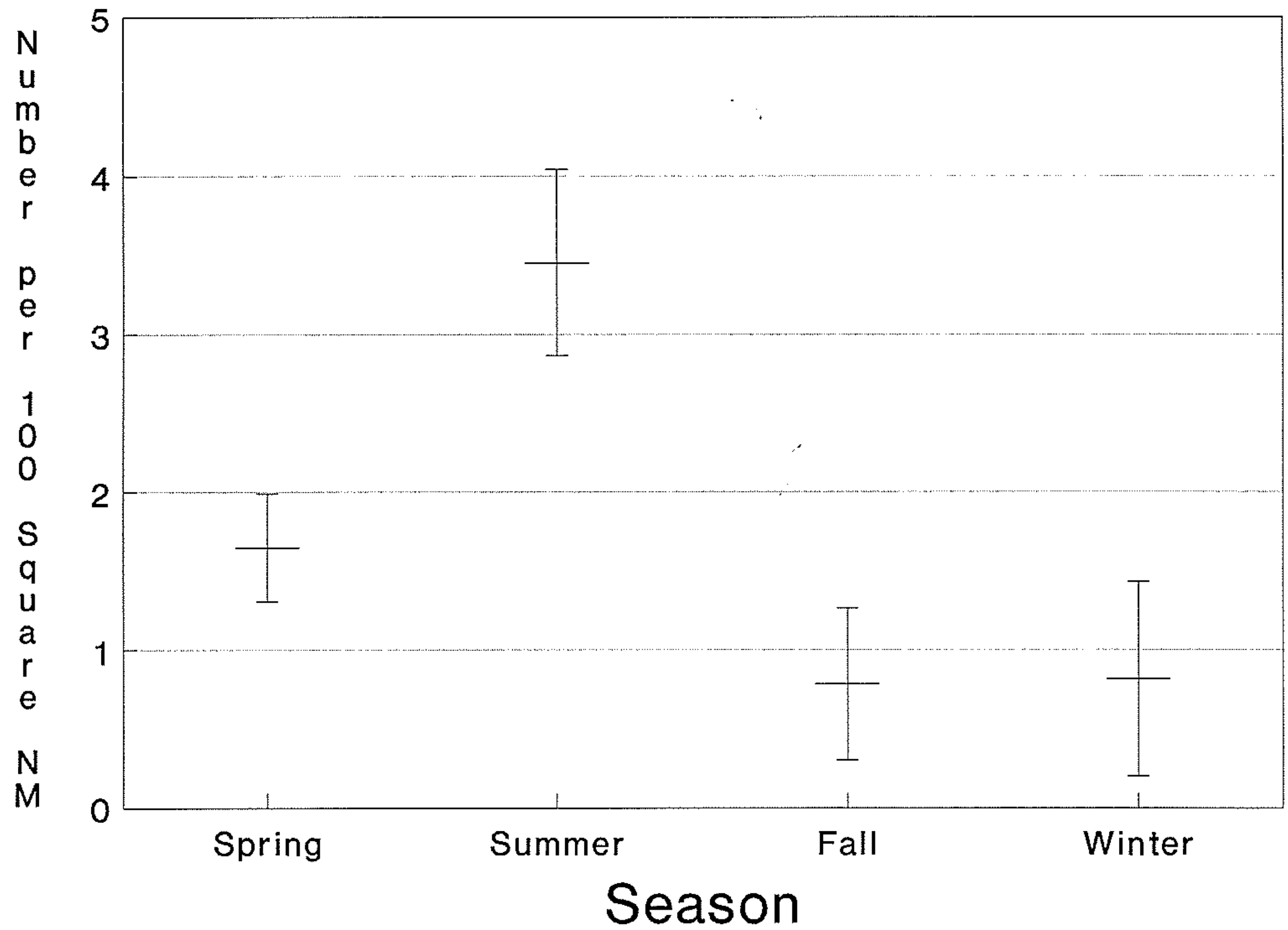
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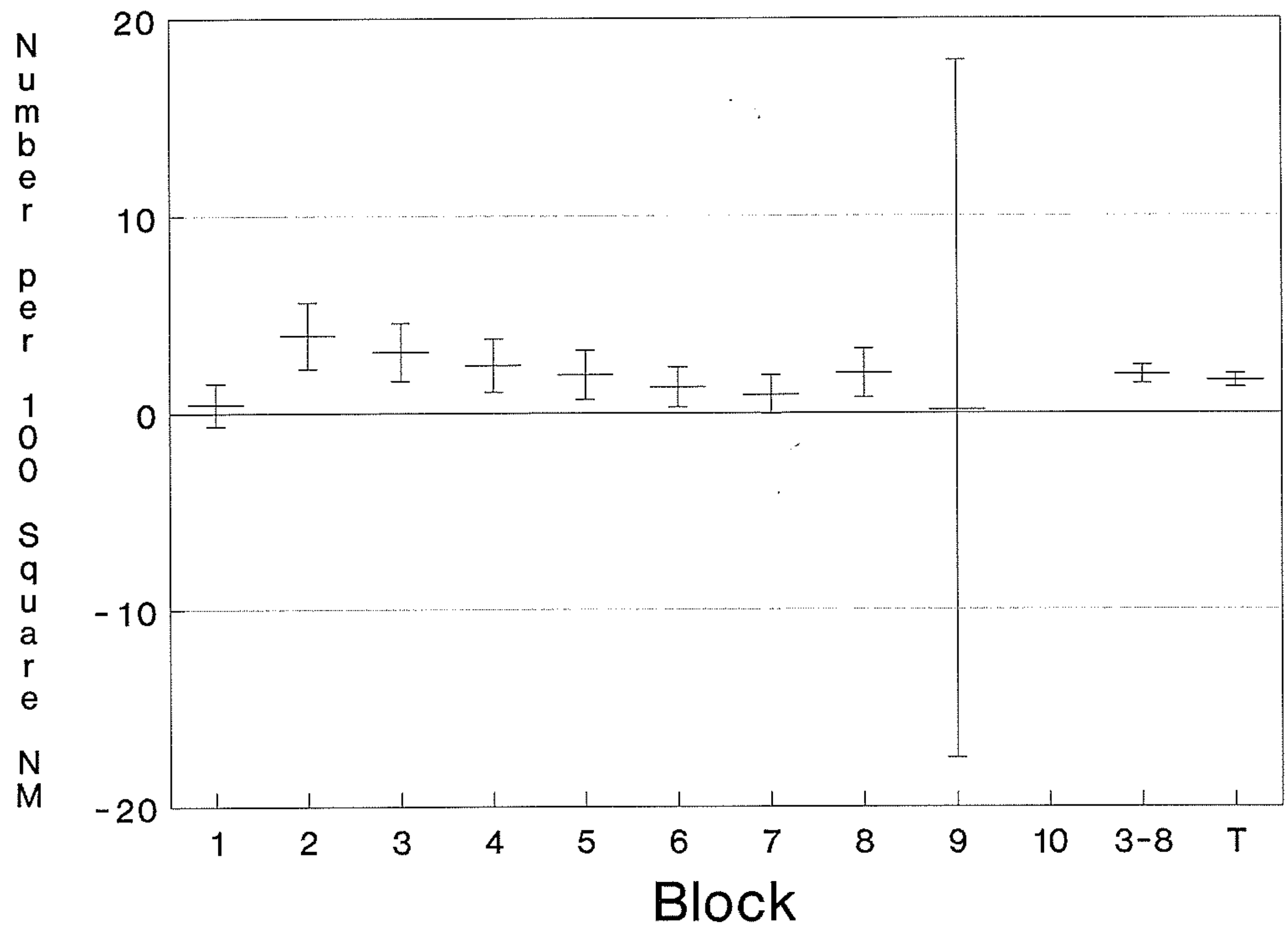
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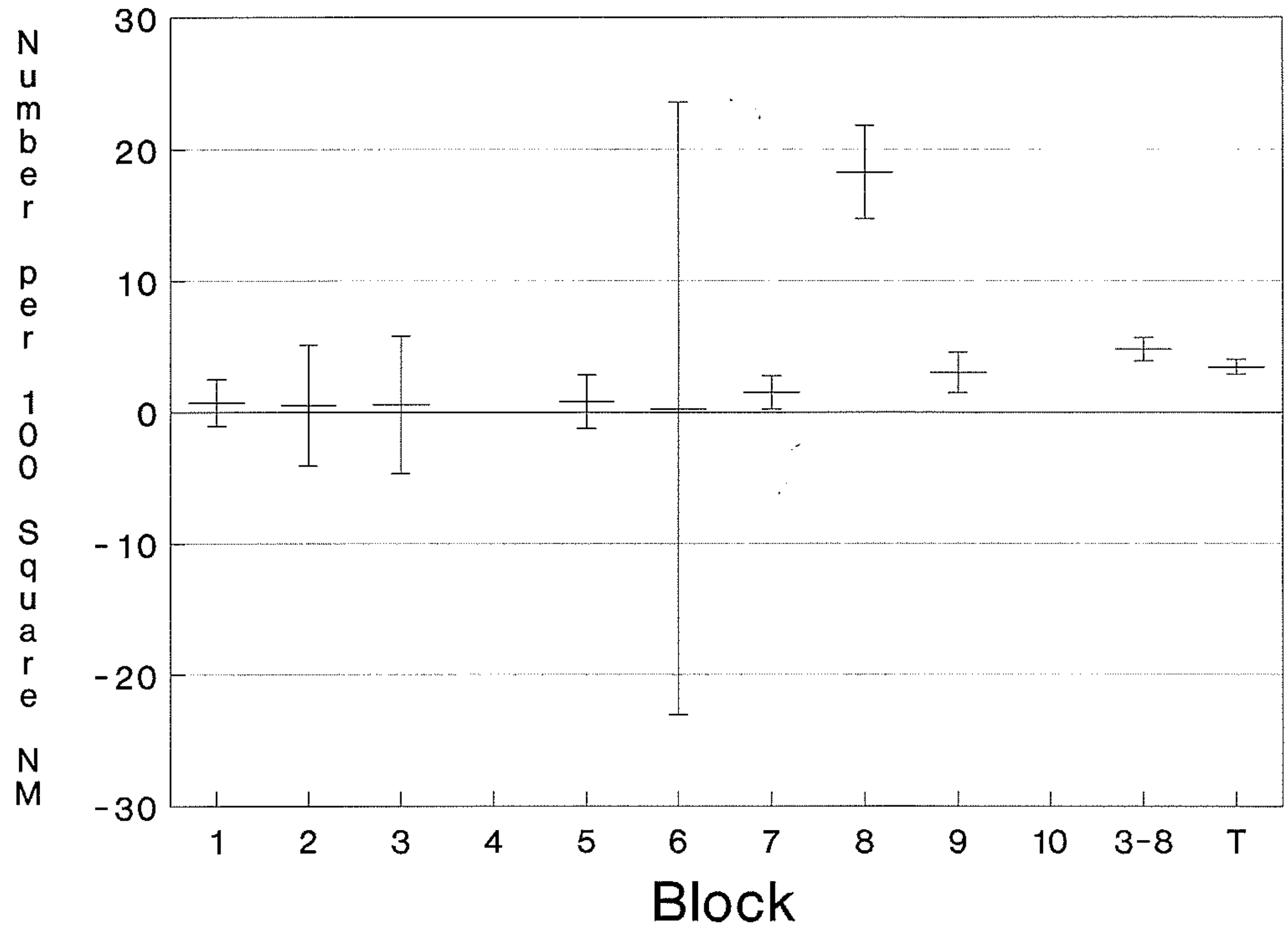
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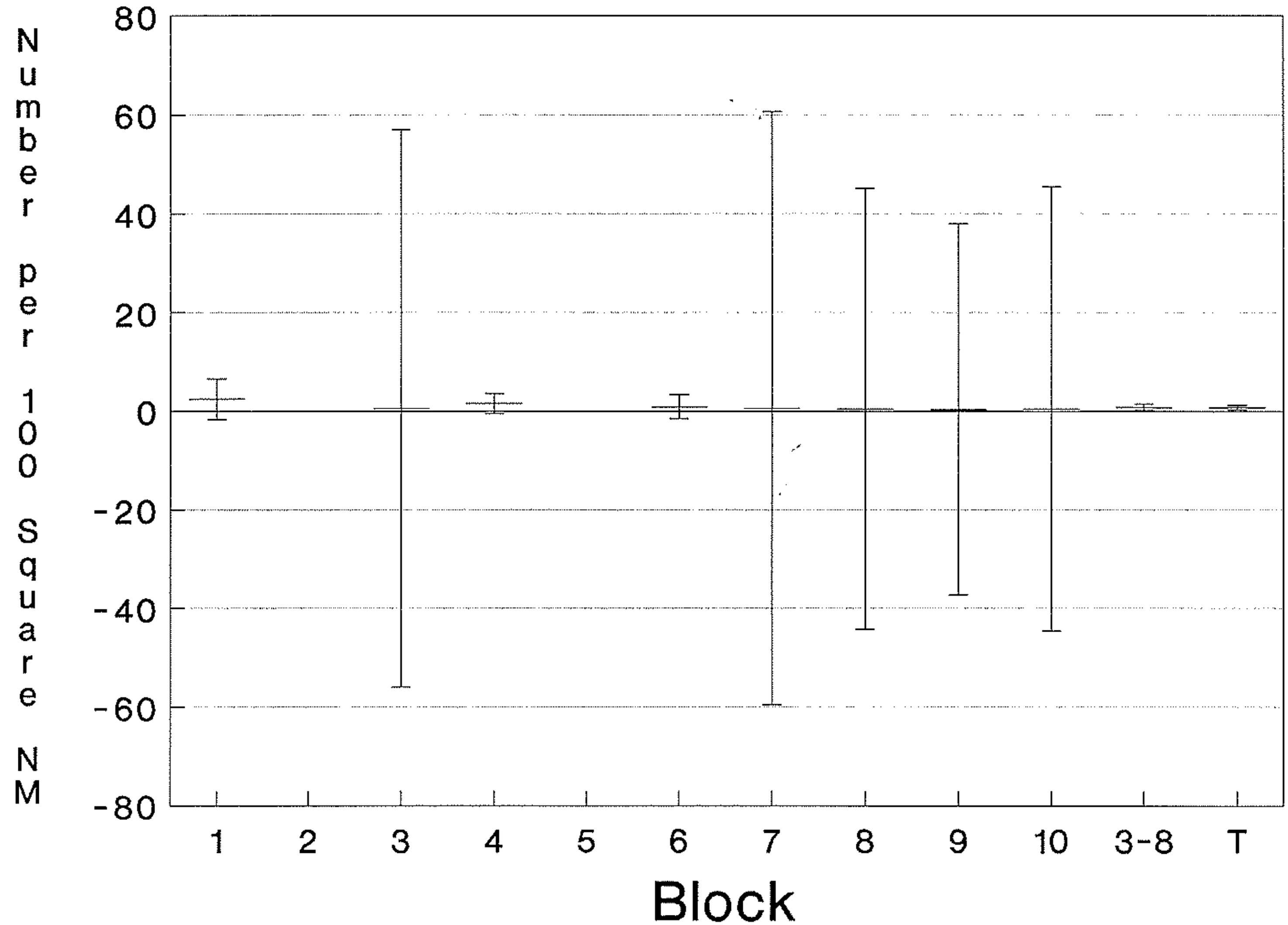
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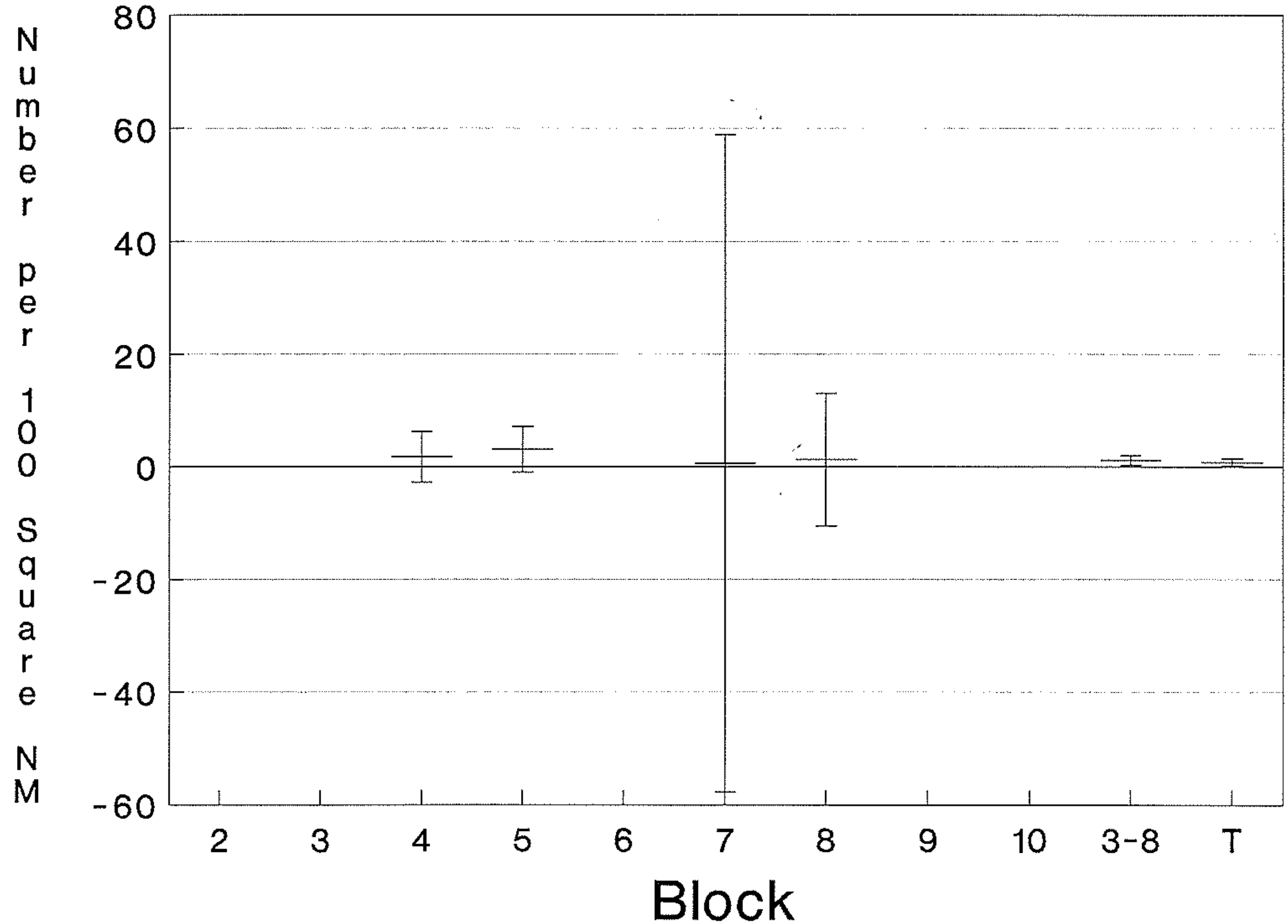
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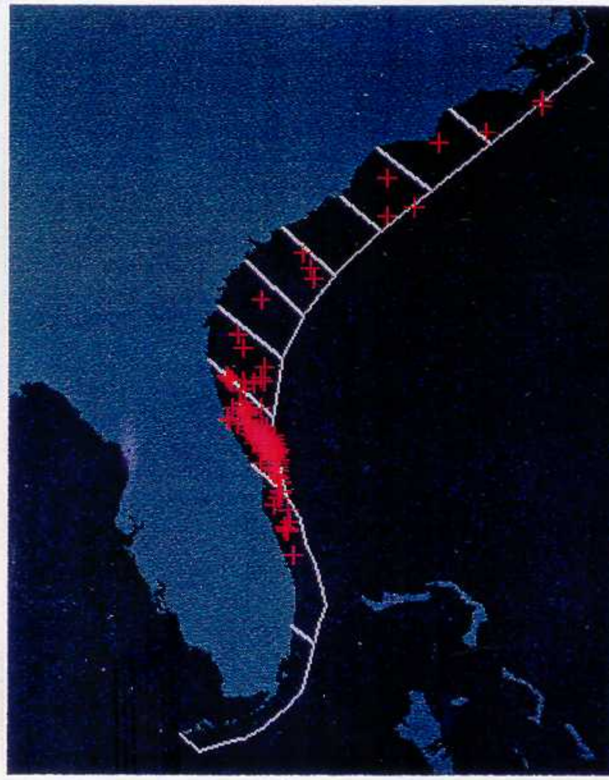
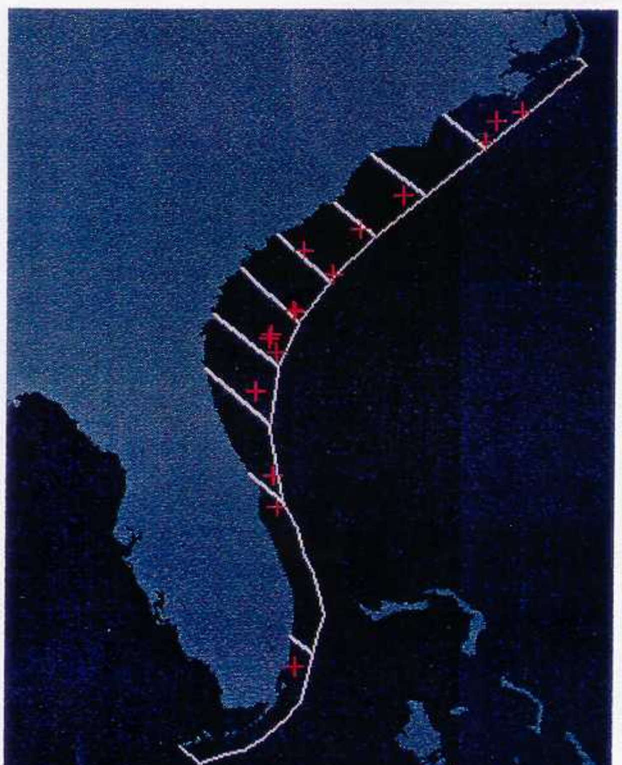


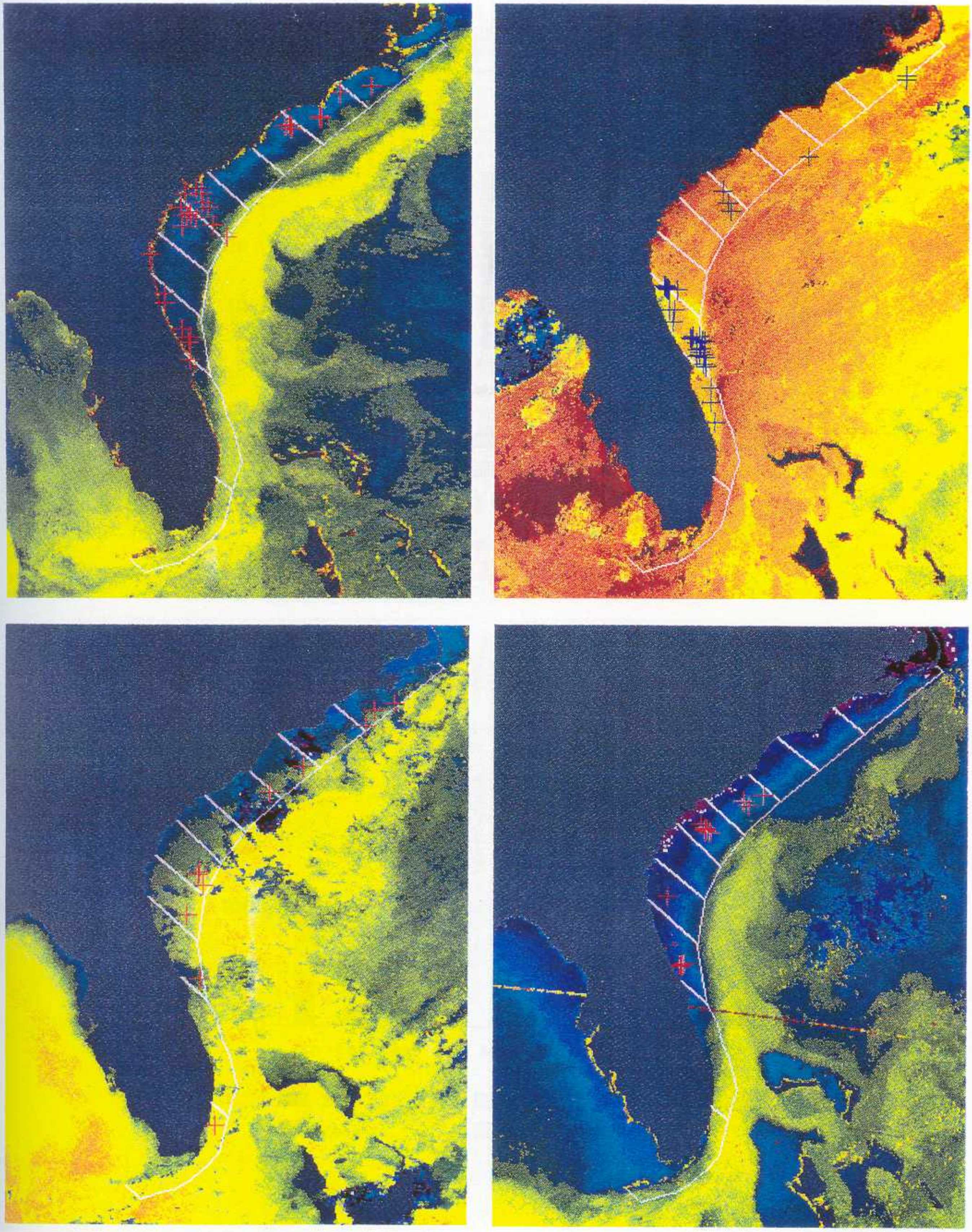

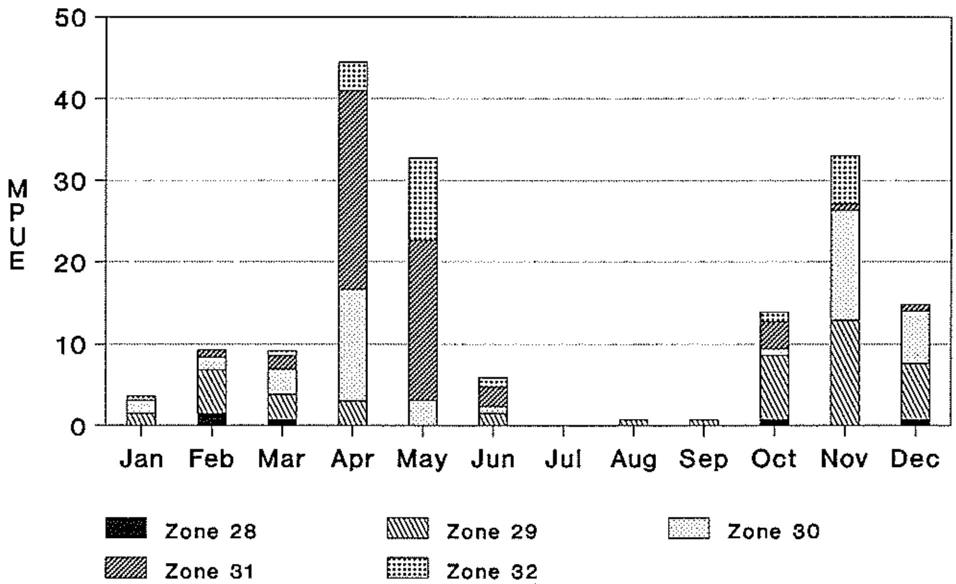

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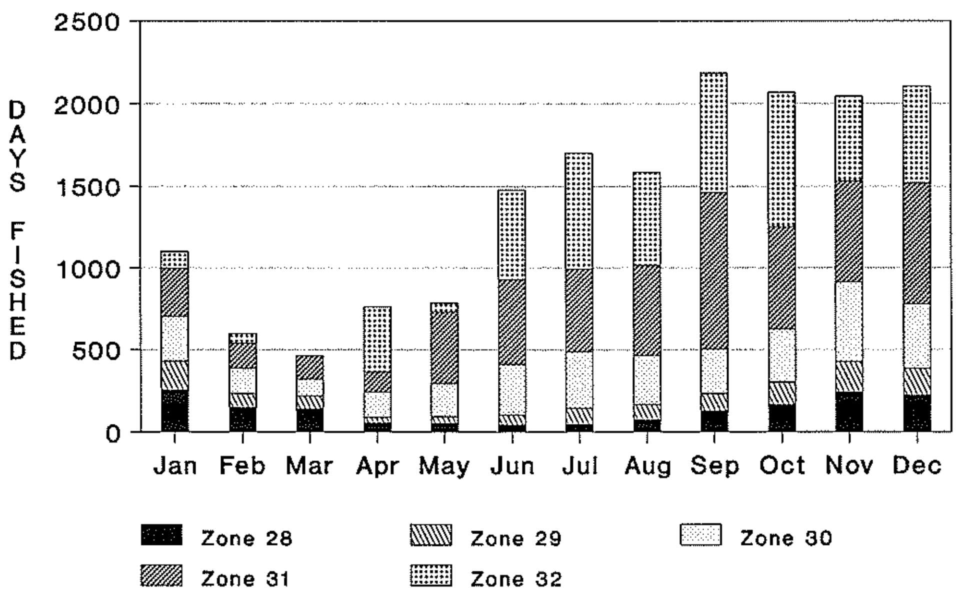
Zone 29
Zone 30
Zone 31
Zone 32



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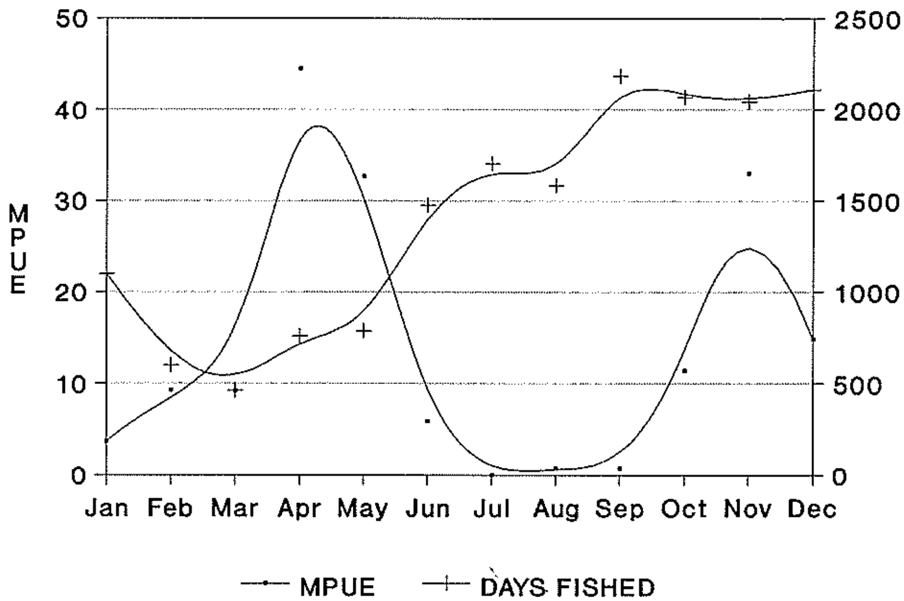
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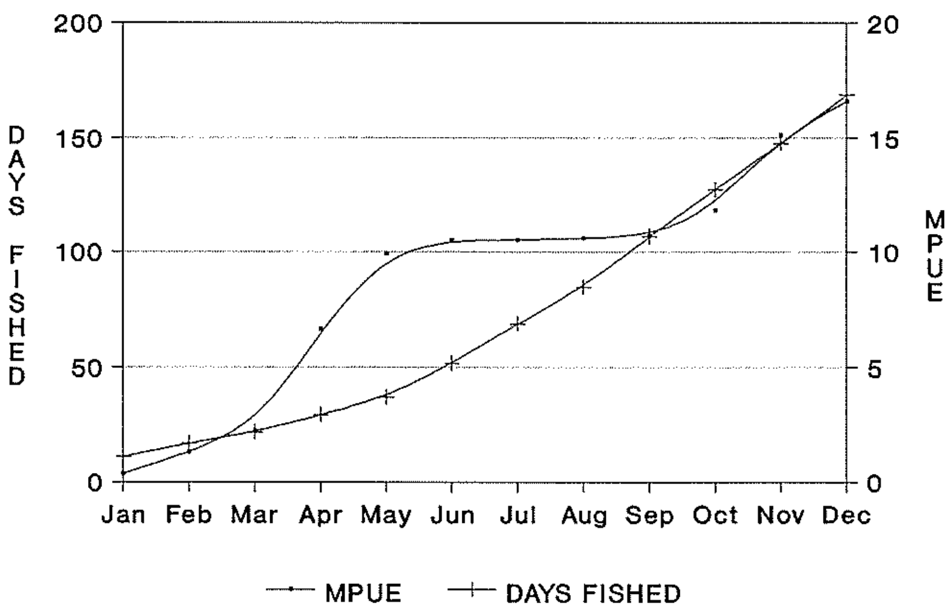
MPUE
DAYS FISHED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